We Be-Lung Together

Target Grade: Elementary/Middle
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Semester: Fall 2018

Please Read

This could be a sensitive subject for students who might know someone who smokes, has lung cancer, asthma, or other respiratory illnesses. Please make sure to be especially sensitive when talking about this subject to not offend any of the students!

Brief Overview

In this lesson, mentees will be learning about the lungs, a key organ of the respiratory system, and how smoke changes it on a cellular structure. Module 1 will introduce students to negative pressure breathing through an interactive model lung. Demo 2 illustrates the obstructive properties of tar by using molasses and a coffee filter to simulate cigarette tar and lung tissue. In module 3, students will be using a balloon and dry ice to simulate how smoke results in a loss of tissue elasticity. Module 4, lung capacity, focuses on teaching students about tidal volume and how smoking impacts people's ability to pull in air using an interactive model.

Main Teaching Goals

- What is the respiratory system?
    - The **respiratory system** is responsible for gas exchange in animals and plants. In many animals specifically, lungs are used for gas exchange.
- How do the lungs use pressure to inflate?
    - The **diaphragm** and muscles of the rib cage contract, expanding the volume of the thoracic cavity, decreasing the pressure, and pulling air into the lungs through the pressure gradient
- How does smoke impact the elasticity and permeability of lung tissue?
    - Smoke decrease the elasticity and permeability of lung tissue by damaging the elastin in the lungs and coating the lung tissue with chemicals
        - **Elasticity**: the ability for distorted tissue to return to its original shape
        - **Permeability**: the ability for gas to be exchanged across tissue
- What are lung capacity and what factors impact them?
    - **Lung capacity**- measures the volume of air that fills the lung during different phases of the respiratory cycle.

- Factors: height, altitude of residency, athleticism

Careers and Applications

The respiratory system is one of the organ systems of the body. Smoke damages this key system, leading to a decline in overall health. To manage this widespread problem, it is essential for doctors and scientists to understand the respiratory system and manage the fallout of smoking and pollution by treating diseases such as lung cancer, asthma, and chronic obstructive pulmonary disease (COPD).

Agenda

- Introduction
- Module 1: Model Lung (15-20 min)
- Module 2: Obstructive properties of tar (10 min)
- Module 3: Dry Ice Balloon (10 min)
- Module 4: Lung Capacity (15-20 min)
- Conclusion

Introduction

Start the lesson off by asking kids what they know about the respiratory system. How much effort does it take them to breathe? (for most people it should take very little) Have them take a few deep breaths and see what muscles they use to breathe. Ask them if inhaling takes more energy or exhaling. Ask them if they know anyone who has asthma or COPD.

The **respiratory system** is responsible for gas exchange in animals and plants. Draw a lung diagram on the board and explain basic anatomy to the students. Focus mainly on talking about how air is drawn into the body mainly through the nose and goes down the upper airway and lower airway and finally into the lungs. The airways further subdivide in the lungs and end in air sacs called **alveoli**, where diffusion of O_2 and CO_2 occurs. Two other structures that people don't often consider an important part of the respiratory system are the **diaphragm** (a muscular dome below the lungs) and the muscles between the ribs. These muscles aid the lungs by expanding the thoracic cavity, making breathing much more efficient. Don't worry if the students don't immediately understand these concepts because they will explore them more in the first module when they make their own model lungs.

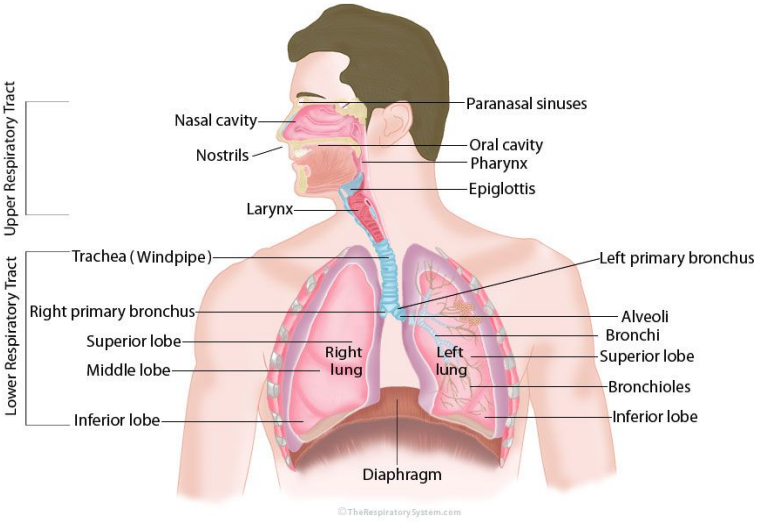

Figure 1: Respiratory system anatomy - *The respiratory system*

Module 1: Lung Model

Introduction

Mentors can begin this lesson by asking students to take a deep breath and then ask what happens to their chest cavity. Students should feel their chests expand as their rib cage and lungs contract. In this module, mentees will be exploring different mechanisms of breathing by using a water bottle and balloons to model how the diaphragm contracts and retracts, creating negative pressure to help the lungs expand.

Teaching Goals

- Muscles of the respiratory system: Mentors should be teaching students about the muscles of the rib cage and the diaphragm and the role they play in the process of creating a pressure gradient that helps air move into the lungs.

Background for Mentors

The human respiratory system takes in oxygen and expels carbon dioxide. The major organs of the respiratory system, the **lungs**, are a pair of spongy, air-filled organs located on either side of the chest. The windpipe conducts inhaled air into the lungs through the branches of the lung. Toward the end of the branches are air sacs called **alveoli**, the site of oxygen and carbon dioxide exchange.

In addition, the more obvious respiratory organs, the muscles of the rib cage and the diaphragm play an important role in **negative pressure breathing**. These structures expand the rib cage during inhalation causing the lungs to increase in size. The expanded lungs are now a much larger container with the same amount of air molecules inside, thus they have a lower pressure than the outside air pressure. The outside air follows the pressure gradient moves from the environment into the lungs.

To explain this concept to the kids, mentors could relate the lungs to two different types of water bottles with caps. One of these bottles could have a very small opening while the other has a much bigger one. When the diaphragm and muscles of the ribs are relaxed, the movie theater only has one theater open and only a limited number of people (air molecules) can

enter. However, the ribs and diaphragm contracting is similar to the movie theater opening up another room. With more seats open, more people (air molecules) can enter and enjoy the movie. Similarly, when the diaphragm contracts, the size of the lungs increase and more air molecules want to enter.

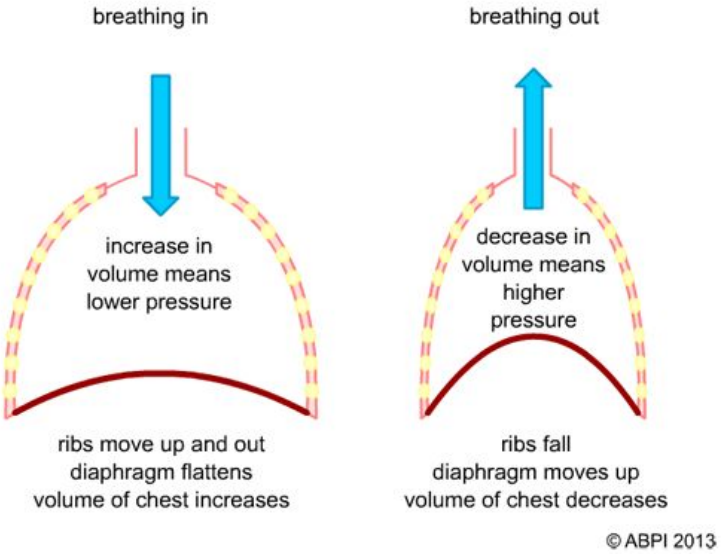

Figure 2: Negative pressure breathing - *Pinterest*

In this lesson, the straw will act as an airway, the balloon inside the bottle acts as a lung, the stretched saran wrap at the bottom acts as a diaphragm, and the inside of the bottle acts as a chest cavity.

When you pull down on the 'diaphragm' saran wrap, the volume inside the bottle gets bigger. This decreases the air pressure inside the bottle so it is lower than the air pressure outside the bottle. Air flows from high pressure to low pressure, so air flows into the straw and fills the 'lung' balloon. When a person inhales, the diaphragm contracts and makes the volume of the chest cavity bigger. Air from outside enters the airways and fills the lungs.

When you let go of the 'diaphragm' saran wrap, the volume inside the bottle gets smaller. This increases the air pressure inside the bottle so it is higher than the air pressure outside the bottle. Air flows out of the 'lung' balloon through the straw. When a person exhales, the diaphragm relaxes and makes the volume of the chest cavity smaller. Air leaves the lungs and flows out of the airways.

Materials

- Empty precut bottles: 3-4 per site
- Drinking straws: 3-4 per site
- small balloon: 10-12 per site
- Saran wrap: 1 foot by 2 foot square per site
- Modeling clay: 1/2 pack per site

Procedure

1. Use the scissors to cut a square of saran wrap that fits over the bottom of the bottle opening. Stretch it over to fit it over the bottom of the precut bottle. Tape the edge of the wrap to the side of the bottle to make sure that it is airtight.
2. Place the balloon and straw into the bottle and use a piece of modeling clay, (wide

enough to cover the opening of the plastic bottle) to wrap around the straw in the bottle opening. Make sure that it's airtight!

3. Slowly pull down on and release the saran wrap at the base of the bottle. Observe the balloon inside the bottle and the air moving in and out of the straw.

Figure 3: Model lung - *Nuvaira*

4. **Two lung model challenge (if extra time)**
    a. Build a more accurate lung model with 2 lungs and a forked airway
    b. Use the scissors to cut a square of saran wrap that fits over the bottom of the bottle opening. Stretch it over to fit it over the bottom of the precut bottle. Tape the edge of the wrap to the side of the bottle to make sure that it is airtight
    c. Attach 2 balloons the ends of 2 straws
    d. Tape the straws together about 2 inches from the top of the balloons
    e. Place both balloons into the bottle and use modeling clay to seal the opening
    f. Slowly pull down on and release the saran wrap at the base of the bottle. Observe the balloon inside the bottle and the air moving in and out of the straw.

Demo 2: The Obstructive Properties of Tar

Introduction

Cigarette tar, or the toxic chemical particles created by using tobacco, often forms a brown or yellow residue. This tar, not nicotine, is actually what is responsible for most of the adverse health effects of smoking. In this demo, mentors will be simulating how an accumulation of tar can inhibit gas exchange by using molasses and coffee filters.

Teaching Goals

- Tar's impact on gas exchange: mentees should be able to describe which area of the lung will be impacted by the tar and why it has this impact
    - Tar kills the tiny hair like structures along the windpipe and the toxins travel

deeper into the lung to the alveoli.

Background for Mentors

According to the National Cancer Institute, cigarette smoke contains more than 7,000 different chemicals. Many of these chemicals are found in the tar that accumulates in the lungs as it is inhaled.

The tar paralyzes and can eventually kill the tiny hair-like structures along the windpipe. These “hairs” help trap pollutants, but when they're disabled, the toxins in tar can travel deeper into the lungs. At the end of the airways of the lungs are the alveoli. Without the cilia to trap the tar, these chemicals migrate to the alveoli, hindering the lungs’ ability to exchange oxygen and carbon dioxide.

In this lesson, mentors will be given 4 funnels and 10 coffee filters. Each demo requires 2 coffee filters, 1 funnel, and 1 plastic water bottle. One coffee filter will be coated with molasses while the other remains clean. These two filters will represent a smoker’s and nonsmoker’s lungs respectively. These two filters will be placed in the funnels and water will be poured over each. The molasses should impede the water as it tries to move through the filter just as oxygen will have a difficult time diffusing across membranes covered in tar.

Figure 4: Molasses and Clean Coffee Filters (Time 0)

Figure 4: Molasses and Clean Coffee Filters (Time 1)

Materials

- Coffee filters: 10 per site
- Funnels: 4 per site
- Plastic water bottles: 4 per site
- Molasses
- Water
- Paper towels

Procedure

1. Place both funnels in the necks of the water bottles.
2. Line the funnels with filter paper.
3. Coat one filter paper with molasses.
4. Pour in the water.
    a. Note how quickly it flows through the clean filter paper and how slowly it flows through the coated paper.

Module 3: Dry Ice Lungs

Introduction

Smoke decreases the elasticity of the lungs, ultimately decreasing the efficiency of expirations and gas exchange. In this module, students will be introduced to this concept using dry ice and balloons.

Teaching Goals

- Smoke and lung elasticity: Mentees should be able to discuss the impact smoke has on the elasticity of the lungs.
    - Smoke decreases the elasticity of the lungs by damaging essential proteins in the lung tissue.
- Lung elasticity and ventilation efficiency: Mentors should focus on teaching students how changes in elasticity impact breathing.

- Decreased elasticity decreases ventilation efficiency of the lungs because the lungs are unable to expel all the air when exhaling.

Background for Mentors

In the lungs, airways end in **alveoli**. Oxygen and carbon dioxide diffuse across the alveoli membrane to and from capillaries.

The toxins in smoke irritate the lung tissue in the lungs and alveoli, damaging the lining. For middle school sites it might be interesting to mention that smoking irreversibly damages **elastin,** a protein that maintains the lung's elasticity and ventilatory function. **Elasticity** is the ability for an object or material to resume its normal shape after being stretched or compressed. Damage to elastin results in respiratory complications including shortness of breath because the lung tissue is unable to "bounce back" after inflation. Thus, the lungs aren't able to expel all the air during exhales.

In this module, the gas from the dry ice represents the smoke while the balloon represents the alveoli. After treatment with dry ice, the balloon should have a much harder time retracting to its original shape. The same thing happens for patients with some respiratory diseases, their alveoli are often extremely expanded and can't retract to expel all the air.

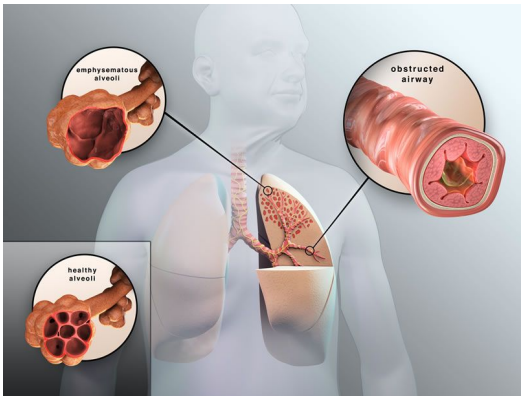

Figure 4: Chronic Obstructive Pulmonary Disease (COPD) - *Nuvaira*

Figure 5: Dry Ice Balloons - *Steve Spangler Science*

Materials

- Balloon: 10 per site
- Dry Ice: ~ 1 cup per site
- Water
- Gloves- 1 pair per site

Procedure

1) First demonstrate dry ice sublimation for the mentees by placing the dry ice in a plastic bottle with about a cup of water.
    a) Mention to the mentees that in this demo, the CO2 generated by the dry ice symbolizes smoke
2) Place a couple pieces of dry ice in the balloon along with a tablespoon of water.
3) Wait a couple minutes as the dry ice fills the balloon so it looks like the second balloon in figure 5. Make sure the balloon doesn't pop!
4) Untie the balloon and remove the piece of dry ice. Let the CO2 disperse.
5) Try having a student blow into the dry ice balloon. Have the same student blow into a balloon which hasn't be treated with dry ice. Note differences in the elasticities.
    a) The balloon treated with dry ice should easier to expand and have a more difficult time retracting back into shape. This is a lot like what happens to the alveoli of smokers

Additional Notes for Mentors

Handle dry ice with care and make sure that the mentees don't come in contact with the ice!

Module 4: Measuring Lung Capacity

Introduction

In this module we will be exploring lung capacity by having students exhale into our lung capacity bags. The bags are marked and mentors can use them to determine the students' lung capacities. Before beginning the module consider asking them what factors they think might impact the volume of air they exhale.

Teaching Goals

- **Lung capacity:** What is lung capacity and what factors impact lung capacity.
    - Lung capacity is the amount of air that fills the lungs during respiration. The main factors that impact lung capacity include: 1) height 2) altitude of residence 3) fitness 4) health choices such as smoking

Background for Mentors

Lung capacity measures the volume of air that fills the lung during different phases of the respiratory cycle. The average lung capacity of an adult male is around 6 liters. Several factors impact lung capacity, including:

	Larger capacity	Smaller capacity
Height	taller	shorter
Altitude of residence	higher	lower

Fitness	fit	obese
Cigarette smoking	nonsmoker	smoker

In this module we will be using the lung bags below to measure lung capacity. Each site will have 3 lung bags. Each site will also be given thin and thick straws to use as mouth pieces. The thicker straw will be used to simulate a “non smoking” lung. The thinner straw stimulates a “smoking lung”. Students should find that they will have a much easier time filling the bag with the thick straw.

Figure 6: Lung capacity bag - *Prolab Science*

Materials

- Lung bags: 3 per site
- Thin straws: ~20 per site (enough for each student to have one)
- Thick straws: ~20 per site (enough for each student to have one)
- Tape

Procedure

- Cut all straws in half.
- Take one lung bag and tape the thin straw to the opening such that there is no air leak.
- Have a student exhale into the bag and use the tick mark to determine the student’s lung capacity.
- Take one lung bag and tape the thick straw to the opening in a similar manner
- Have students take turns measuring their lung capacities.
    - Have students observe differences between breathing through the large and small straws. They should observe that the large straws are easier to breathe through.
- **Exercise challenge (if there’s extra time):**
    - Record students’ resting lung capacities.
    - Then have students exercise for 30 secs, 1.5 mins, 2 mins and record your lung volumes. How does exercise time affect lung volume? Make a graph!
        - When you exercise more, your lungs work harder to provide oxygen to the muscles, so the volume of air supplied to your lungs increases.

Additional Notes for Mentors
Make sure to change straws between students and warn students not to spit into the bags!

Conclusion

In conclusion, ask the mentees what they learned about lung anatomy today and how the muscles of the respiratory system aid in breathing.

- The diaphragm and the muscles of the rib cage help expand the ribs and promote negative pressure breathing (Module 1)

What are the three main impacts cigarettes have on the lungs that we covered in the lesson today?

- Cigarettes coat the lung tissue in tar which hinders the lungs' ability to perform gas exchange (Module 2)
- Chemicals in smoke irritate the lung tissue, decreasing the ability for the tissue to recoil when breathing (Module 3)
- Smoking decreases overall lung capacity, causing a smaller amount of oxygen to reach the bloodstream (Module 4)

References

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- Obstructive lung disease, Webmd: https://www.webmd.com/lung/obstructive-and-restrictive-lung-disease#1
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- Model lung, Nuvaira: http://www.nuvaira.com/wp-content/uploads/2013/01/COPD_Rev-E_large.jpg
- COPD, Nuvaira: https://www.nuvaira.com/about-copd/
- Lung capacity bag, Prolab Scientific: http://prolabscientific.com/Lung-Volume-Kit-Set-of-4-Kits.html
- Dry ice balloon, Steve Spangler Science https://www.stevespanglerscience.com/lab/experiments/dry-ice-balloon/

Summary Materials Table

Material	**Amount per Group**	**Expected $$**	**Vendor (or online link)**
Lung capacity Tubes	3 per site	$32.82	Home Science
Thick straws	15 per site		Inventory
Coffee filters 600 pack	10 per site	$5.91	Amazon
Molasses	1-2 cups per site	$17.49	Google Express
Paper towels	1 roll per site	$14.49	Google Express
Balloons	15 per site		Inventory
Thin straws	20 per site		Inventory
Water bottles (precut)	4-5 per site		Inventory/Have mentors collect
Water bottle (uncut)	4 per site		Inventory/Have mentors collect
Masking tape	2 roll per site		Inventory
Funnels	4 per site		Inventory Amazon
Saran Wrap	1 roll for all the sites (pre cut into 1 foot by 2 foot squares)	$4.84	Amazon
Dry ice	1 cup per site		Get from lab/Safeway
Scissors	3-4 per site		Inventory
Clay	48 packs	$13.98	Amazon
Gloves	1 pack	$8.45	Amazon